Exelon Generation.

10 CFR 50.73

RA-14-095

November 11, 2014

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555 - 0001

Oyster Creek Nuclear Generating Station
Renewed Facility Operating License No. DPR-16
NRC Docket No. 50-219

Subject: Licensee Event Report (LER) 2014-003-00, Technical Specification Prohibited Condition Caused by Emergency Diesel Generator Inoperable for Greater than Allowed Outage Time

Enclosed is LER 2014-003-00, Technical Specification Prohibited Condition Caused by Emergency Diesel Generator Inoperable for Greater than Allowed Outage Time. This report is submitted in accordance with 10 CFR 50.73(a)(2)(i)(B), any operation or condition prohibited by the plant's Technical Specifications.

This event did not affect the health and safety of the public or plant personnel. This event did not result in a safety system functional failure. There are no regulatory commitments made in this LER submittal.

Should you have any questions concerning this letter, please contact Michael McKenna, Regulatory Assurance Manager, at (609) 971-4389.

Respectfully,

Jeffrey P. Dostal
Plant Manager
Oyster Creek Nuclear Generating Station

Enclosure: NRC Form 366, LER 2014-003-00

cc: Administrator, NRC Region 1
NRC Senior Resident Inspector - Oyster Creek Nuclear Generating Station
NRC Project Manager - Oyster Creek Nuclear Generating Station

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NRC FORM 366 (01-2014)

U.S. NUCLEAR REGULATORY COMMISSION

LICENSEE EVENT REPORT (LER)

(See Page 2 for required number of digits/characters for each block)

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4. TITLE

Technical Specification Prohibited Condition Caused by Emergency Diesel Generator Inoperable for Greater than Allowed Outage Time

5. EVENT DATE			6. LER NUMBER			7. REPORT DATE			8. OTHER FACILITIES INVOLVED	
MONTH	DAY	YEAR	YEAR	SEQUENTIAL NUMBER	REV NO.	MONTH	DAY	YEAR	FACILITY NAME	DOCKET NUMBER
09	12	2014	2014 -	003	- 00	11	11	2014	N/A	N/A
									N/A	N/A

9. OPERATING MODE	11. THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR §: *(Check all that apply)*			
N	☐ 20.2201(b)	☐ 20.2203(a)(3)(i)	☐ 50.73(a)(2)(i)(C)	☐ 50.73(a)(2)(vii)
	☐ 20.2201(d)	☐ 20.2203(a)(3)(ii)	☐ 50.73(a)(2)(ii)(A)	☐ 50.73(a)(2)(viii)(A)
	☐ 20.2203(a)(1)	☐ 20.2203(a)(4)	☐ 50.73(a)(2)(ii)(B)	☐ 50.73(a)(2)(viii)(B)
	☐ 20.2203(a)(2)(i)	☐ 50.36(c)(1)(i)(A)	☐ 50.73(a)(2)(iii)	☐ 50.73(a)(2)(ix)(A)
10. POWER LEVEL	☐ 20.2203(a)(2)(ii)	☐ 50.36(c)(1)(ii)(A)	☐ 50.73(a)(2)(iv)(A)	☐ 50.73(a)(2)(x)
100	☐ 20.2203(a)(2)(iii)	☐ 50.36(c)(2)	☐ 50.73(a)(2)(v)(A)	☐ 73.71(a)(4)
	☐ 20.2203(a)(2)(iv)	☐ 50.46(a)(3)(ii)	☐ 50.73(a)(2)(v)(B)	☐ 73.71(a)(5)
	☐ 20.2203(a)(2)(v)	☐ 50.73(a)(2)(i)(A)	☐ 50.73(a)(2)(v)(C)	☐ OTHER
	☐ 20.2203(a)(2)(vi)	☒ 50.73(a)(2)(i)(B)	☐ 50.73(a)(2)(v)(D)	Specify in Abstract below or in NRC Form 366A

12. LICENSEE CONTACT FOR THIS LER

FACILITY NAME	TELEPHONE NUMBER *(Include Area Code)*
Michael McKenna, Regulatory Assurance Manager	(609) 971-4389

13. COMPLETE ONE LINE FOR EACH COMPONENT FAILURE DESCRIBED IN THIS REPORT

CAUSE	SYSTEM	COMPONENT	MANU-FACTURER	REPORTABLE TO EPIX	CAUSE	SYSTEM	COMPONENT	MANU-FACTURER	REPORTABLE TO EPIX
B	EK	DG	E147	Y	N/A	N/A	N/A	N/A	N/A

14. SUPPLEMENTAL REPORT EXPECTED	15. EXPECTED SUBMISSION DATE	MONTH	DAY	YEAR
☐ YES *(If yes, complete 15. EXPECTED SUBMISSION DATE)* ☒ NO		N/A	N/A	N/A

ABSTRACT *(Limit to 1400 spaces, i.e., approximately 15 single-spaced typewritten lines)*

On July 28, 2014, Emergency Diesel Generator No. 2 (EDG-2) was being operated for its bi-weekly one-hour load test run, when alarms "EDG 2 ENGINE TEMP HI" and "EDG 2 DISABLED" were received. Operations manually shut down EDG-2 due to an apparent cooling problem with the diesel engine. During initial troubleshooting, the fan duct was opened to access the upper fan shaft and it was found that the cooling fan shaft had failed. Without the fan in service, radiator heat transfer performance was degraded, leading to high jacket water (coolant) temperatures and associated alarms.

On September 12, 2014, an Equipment Apparent Cause Evaluation (EACE) for the fan shaft failure was completed. The EACE determined that the remaining shaft life would have met the 24-hour mission time of approximately four test cycles or approximately 43 days prior to the failure. Based on the EACE determination, EDG-2 would not have been able to meet its mission time of 24 hours for approximately 43 days, which is greater than the Technical Specifications (TS) Allowed Out of Service Time (AOT) of seven days.

Therefore, this issue is reportable under 10 CFR 50.73(a)(2)(i)(B) as an Operation or Condition which was Prohibited by the plant's Technical Specifications.

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NARRATIVE

Description of Event

On July 28, 2014, Emergency Diesel Generator No. 2 (EDG-2) was being operated for its bi-weekly one-hour load test run, when alarms "EDG 2 ENGINE TEMP HI" and "EDG 2 DISABLED" were received. Operations manually shut down EDG 2 due to an apparent cooling problem with the diesel engine. During initial troubleshooting, the fan duct was opened to access the upper fan shaft and it was found that the cooling fan shaft had failed. Without the fan in service, radiator heat transfer performance was degraded, leading to high jacket water (coolant) temperatures and associated alarms.

Equipment Description

Oyster Creek Nuclear Generating Station is equipped with two identical EDG units. The function of the EDGs is to provide AC power to the Class 1E busses upon a loss of the off-site power. The EDG must be able to provide this power rapidly, within 10 seconds, upon demand. This condition is referred to as a fast start signal. If started with a fast start signal, a high jacket water temperature condition will not trip the EDG.

The EDG units are General Motors Corporation, Electromotive Division (EMD) Model EMD 20-645E4, 20-cylinder, 2-cycle, turbo-intercooled diesel engines, which drive their respective EMD A20C AC generators. The EDGs are installed in enclosures inside the EDG vaults. Engine auxiliaries retain a locomotive-type layout with the radiators in duct compartments over the engines. Cooling air to each engine is drawn into this duct by a large fan at the south end of the enclosure. The fan is supported and rotated by a belt-driven shaft that is in turn rotated by a power-takeoff shaft connected to the engine. The failure location was at a groove in which a bearing retainer is mounted. The failure location could not be visually inspected without removing the bearing retainer and as such, would not be identified on operator rounds or normal maintenance.

Analysis of Event

Following the event, a complex troubleshooting team was formed to identify and investigate possible failure modes. Bearing issues, bent fan shaft, fan imbalances, metallurgical defect, and incorrect belt tension were considered. Some of the follow-up actions to support or refute possible failure modes required laboratory failure analysis. Consequently, the shaft section and bearing parts were quarantined and sent to Exelon PowerLabs (PL) for examination.

PowerLabs Report Summary

Laboratory evaluations indicated the shaft failure was caused by rotational bending fatigue. Investigations revealed that based on the smooth, flat, and planar fracture surface features and relatively small final overload area (approximately 10-20% of the total fracture surface), propagation occurred by a high cycle–low stress fatigue mechanism. The cracking initiated at the shaft groove diameter transition, which would act as a high stress concentrator. Multiple ratchet marks (which are indicative of multiple crack planes) were observed around the periphery and imply that propagation was due to rotating-bending fatigue. No material defects were observed on the shaft outer surface that would have contributed to the failure initiation.

PL also noted that the bearing contained minor damage that was considered collateral damage from the failed shaft. There was no misalignment of the roller paths on the inner or outer races. In addition, the pillow block base and bolt holes were not worn, which suggested the base was secured during operation.

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Findings presented in the PL report lead to a review of fan belt tension, which was initially identified as a potential failure mode. Per Maintenance procedure MA-OC-86103-100, "Diesel Generator Fan Belt Replacement," belt tension is set at 60Hz (~5800 lbs hub load equivalent). This setting was discussed with Engine Systems Incorporated (ESI) and found to be 37% higher for the fan horsepower requirement. Technical Evaluation 01686101-06 concluded 47.4 ±2 Hz (~3600 lbs hub load equivalent) is an appropriate setting

Structural Integrity Associates (SIA) was consulted to perform a stress analysis to determine potential causes that could further explain why the fan shaft failed. Additionally, they were asked to analyze fatigue crack initiation and growth, and to determine at what point in the EDG-2 operating cycle the fan shaft had remaining life of 24 hours (EDG mission time).

Structural Integrity Associates Report Summary

SIA investigations revealed that crack growth occurred during the last test run (less than one hour). Beachmarks, features that typically define stops and starts of fatigue crack growth, combined with simulated crack growth data show that the shaft failure would have happened during the last load test. The remaining shaft life would have met the 24-hour mission time approximately four test cycles or approximately 43 days prior to shaft failure.

SIA investigations indicated that a hub load of 5800 lbs. would produce stresses in the reduced (shaft groove transition) section of the shaft of 19.15 ksi, which is at or just below the endurance limit of the shaft material. Endurance limit is defined as the amplitude (or range) of cyclic stress that can be applied to the material without causing fatigue failure. A slight increase in stress for whatever reason would cause the predicted fatigue life to move from infinite to approximately 250 hours based on a change for 19.15 ksi to 20.5 ksi, (about 165 tests). A smaller stress increment above the 19.15 ksi, or smaller, non-continuous time above the 19.15 ksi (e.g., run starts at full belt tension plus stress increment; over time belt loosens slightly to drop stress below 19.15 ksi) would increase the number of cycles and tests to crack initiation.

SIA concluded that at the loads the shaft might experience, fatigue life (both initiation and growth) would be very sensitive to small changes in the load or Stress Concentration Factor (SCF), a dimensionless number used to quantify how concentrated the stress is in a material. The stress amplitude at some point in time must have been higher than 19.15 ksi or that SCF is higher than three for the crack to initiate. SCF is affected by the dimensions of shaft transitions, such as the bearing groove; the smaller the radii or fillet, the higher the SCF.

SIA determined the potential causes of rotational bending fatigue as: 1) Hub loading exceeded the material properties, or 2) defect that produced a stress riser at the groove location (more notched or angular versus a U-shape with radius bends). Either condition could result in stress conditions where the SCF exceeds its design limit of less than or equal to three.

Cause of Event

When reviewing the timeline for potential causes in support of SIA's conclusions, two instances were found worth considering, a fan shaft failure in 1993 and added belt tension in 2005. First, the shaft failure in 1993 shows how susceptible the bearing grooves locations are to imperfection. Questions regarding design details and manufacturing practices were discussed with ESI. Design information, such as dimensions, is limited to vendor manual references, and specifics of bearing retaining groove, as stated by ESI, was left at the discretion of the machinist.

Second, the then recommended tension frequency of 60 Hz is important because it increases the likelihood of the shaft exceeding the endurance limit due to reducing stress margin. An important result from the SIA investigations is that 60 Hz of tensioning frequency, although very high, was most likely not enough to single-

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handedly cause the failure. It was noted that 60 Hz corresponds to approximately 19.15 ksi of stress, which is at or just below the endurance limit. If the shaft was consistent in diameter and stress relief contour profile throughout, it could effectively operate over an infinite number of cycles. Therefore, the plausible failure mode is attributed to manufacturing deficiency or imperfection such as a scratch or nick that increased the stress above the endurance limit. A manufacturing deficiency is the more likely of the two causes based on that fact the PL investigation found no instances of imperfections. Furthermore, the EDG sets are adapted from transportation engines. The original Equipment Manufacturer Design (EMD) was qualified for safety-related service and subsequent parts procured through companies such as ESI. The shafts in service as well as spares were provided to the plant in the late 1960s. Discussions with ESI indicated limited information (dimensions and material) was on file for shaft part number 8441753. In addition to stress relief contours, other factors such as surface finish, heat treatment, etc., can affect material fatigue resistance.

The apparent cause of the failure was found to be higher than average stress concentration factor due to manufacturing deficiency at the grooved location.

The high cycle fatigue mechanism as evaluated by PL and SIA concluded that either excessive hub loading (belt tension) or a notch type defect were the most likely failure mechanisms. It is important to note that the SIA report data approximates material properties of the shaft. Design and fabrication variables such as material hardening, surface finish, EMD shaft design process, machinist proficiency, etc. are variables whose combined impact cannot be assessed.

ESI indicated that limited detail is available on the shaft design, including control of parameters such as stress relief profiles, and finish. Further, control of the groove profile was left to the skill of the fabricating machinist. Minimal design data also challenges the ability to assess shaft health. It is likely that the failed shaft had lower stress margin due to unfavorable variances in fabrication. This condition would have lowered the margin between operational stresses and design stresses leading to its transition from infinite endurance to a finite life from installation in 1993 to end-of-life in 2014. Therefore, a deficiency in the groove profile fabrication is the most likely cause for the shaft failure.

Contributing to the failure was that belt tension, as outlined in station procedure, did not provide adequate margin necessary to address stress risers at the notch.

In 2005, Maintenance procedure MA-OC-86103-100 was issued to specify the 60 Hz belt tension setting, but no technical evaluation was performed or vendor document referenced to review this setting. The 60 Hz belt tension setting is excessive; which resulted in:

A. Reduced margin to the shaft stress design limits.
B. A possibility that the belt was tensioned to a point where hub loading combined with stress risers originating from control of the groove configuration exceeded the shaft fatigue endurance limit.

The following immediate actions were taken:

- Replaced EDG-2 fan shaft.
- Performed Ultrasonic Testing of the EDG-1 fan shaft.
- Obtained failure Analyses for failed fan shaft (PL and SIA).
- Performed technical evaluation to specify correct fan belt tension.
- Performed a “Deep Dive” check-in assessment of station EDG maintnenance and operating strategies.

Corrective Actions

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In order to address the Apparent Cause the following actions were (or are being) taken:

- Repaired EDG-2 failed fan shaft by completing a work order to replace the shaft.
- The EDG-1 fan shaft will be replaced by May 15, 2016.

In order to address the Contributing Cause the following actions were (or are being) taken:

- Technical Evaluation was performed to determine the correct belt tension for both EDG-1 and EDG-2
- Re-tensioned EDG-1 and 2 fan belts based on Technical Evaluation.
- Revise station procedures to incorporate correct fan belt tension specified in Technical Evaluation.

Previous Occurrences

DR 93-387 EDG-2 Fan Shaft Failure - In August 1993, the EDG-2 fan shaft failed during routine testing. The cause of the failure was a combination of two factors: 1) the existence of a weld overlay in the vicinity of the bearing sleeve attachment that created an extremely hard subsurface layer, and 2) a machined groove immediately adjacent to the bearing sleeve attachment that extended to a depth corresponding to this extremely hard zone. The result was the initiation of a crack that propagated by torsional fatigue until failure.

Component Data

Component	IEEE 805 System ID	IEEE 803A Function
Emergency Diesel Generator	EK	DG